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INFLUENCE OF TROPOSPHERIC PROCESSES ON CHANGES IN THE TEMPERATURE FIELD AND CIRCULATION IN THE STRATOSPHERE

by Kh. P. Pogosyan

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ABSTRACT

Results of study of the influence of the tropospheric processes on air circulation in the stratosphere are presented in this paper. It is shown that intensively developing tropospheric vortexes, particularly over the continents during the winter, influence substantially the change of circulation in the lower stratosphere. The rising large scale turbulence exchange, followed by advection and convective motions covering both the troposphere and stratosphere, is of great importance in this process.

This paper also presents the information about the synchronic change of geopotential both in the troposphere and stratosphere, the height up to which the atmospheric vortexes extend during the winter, etc.

The problem of the interaction of processes in the troposphere   /30* and the stratosphere has been discussed in meteorological literature for a long period of time. Even in 1940, the study (Ref. 1) showed that there was no justification for the ideas regarding the "stratospheric control" which had existed for 30 years (Ref. 2). The leading role of the troposphere in the development of atmospheric processes is shown in the study (Ref. 1) by determining the amount of energy in a system of thermodynamic solenoids .

In recent years, there has been an increase in studies on the effect of processes developing in the troposphere and stratosphere due to the expansion of observations by means of radiosondes and meteorological rockets. It is impossible to explain the significant intraseasonal changes in the temperature field, the geopotential, and the wind, which are detected in the stratosphere of the extratropical latitudes, by radiant heat exchange. This is due to the fact that the diurnal changes in the air temperature exceed by several factors the radiation heating and cooling of the stratosphere in this sphere (Ref. 3). In addition,

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* Note: Numbers in the margin indicate pagination in the original foreign text.

these changes - particularly the temperature rise in the stratosphere of the Arctic - could not be explained in winter, when radiant heating of the air is not possible at high latitudes under the conditions of the polar night.

Several authors have studied the sharp temperature rise in the stratosphere of the Arctic in winter. However, up until the present there has been no uniform opinion as to the nature of this phenomenon. Some researchers explain these changes by solar activity (Ref. 4, 5); other researchers explain them by advection of the warm air from the mean latitudes (Ref. 6, 7) or by the descending movement of the air and adiabatic heating of it (Ref. 8-10). Certain researchers explain them by the simultaneous effect of advection and the descending movement of air in the baroclinic zones (Ref. 11-14). This diversity of opinions can be primarily explained by insufficient data from aerological observations in the Arctic and by the incomplete explanation of advective and non-advective temperature changes in the stratosphere. In addition, as a rule researchers have studied processes in the stratosphere apart from processes in the troposphere. In principle, it is incorrect to study non-periodic temperature fluctuations and air circulation in the stratosphere in this way, although the conditions under which air undergoes radiant heating in these two spheres are different.

The mean monthly maps of absolute topography show that the structure of the isohypse field in the stratosphere, in areas of 200, 100, 50 and even on 30 and 10 mb, have the features of the areas lying below in winter, particularly at 500 mb. The characteristic seasonal structural features of the relative and absolute geopotential fields, created due to the influence of the underlying area (continents and oceans) and the wind activity, find expression in the stratosphere. It is not accidental that many researchers have established the fact that in every case sharply- /31 expressed meridional circulation in the troposphere and the lower stratosphere preceded the winter temperature rise in the stratosphere of the Central Arctic through the northern Pacific Ocean or the Atlantic.

In works which were published previously (Ref. 12, 15), the author advanced a hypothesis to explain the nature of intraseasonal changes in the temperature field and circulation in the stratosphere. According to this hypothesis, the strongly-developing atmospheric winds had a significant influence on the stratospheric processes, including the formation of very anomalous temperature rises in the Arctic. It was shown that a group of strong cyclones, causing intense intra-latitudinal air exchange in the troposphere, modifies the circulation system in the winter at altitudes up to 25-30 km, and in individual cases even higher. In summer, the reverse is the case. Cyclones and anticyclones frequently reach levels of 20 km, but only rarely are there traces of them at an altitude of 20-22 km.

According to the studies of Ye. I. Lubentsova, a closed cyclone system of isohypses is frequently encountered at altitudes of 20-25 km

and above in winter. In summer, it is only encountered up to levels of 20-22 km. Both in winter and in summer, as a rule cyclones in the stratosphere occur to the north of 40-45° N with a magnitude H in a 500 mb area equalling 510-520 decameters in winter, and 540-550 decameters in summer.

What produces the differences in the extent of cyclone circulation in the stratosphere in the winter and summer? It is known that the direction of the horizontal temperature gradient above the tropopause usually reverses in the developing baric formations, no matter what the season of the year, due to the dynamics of the processes. However, the direction of the temperature gradient established above the tropopause in summer remains up to an altitude of 25-30 km, and - judging from the nature of the seasonal temperature field in the stratosphere (Ref. 16) - it apparently remains up to the level of maximum temperatures - i.e., 50-60 km. In winter, this usually extends up to an altitude of 15-20 km above the mean and high latitudes, if the direction of the horizontal temperature gradient above the tropopause is just the reverse of that for the troposphere. Above this altitude, the direction of the temperature gradient usually becomes the same as in the troposphere.

Thus, the seasonal nature of the temperature gradient direction during winter and summer in the stratosphere, which is caused by radiant heat exchange particularly at the high latitudes, leads to different results under the conditions of the polar night and the polar day. During winter, the magnitude of the horizontal temperature gradients increases with altitude between the mean and high latitudes in the stratosphere, the temperature constants increase, and the winds intensify reaching altitudes of 25-35 km at more than 40-50 m/sec. On the other hand, in summer the wind velocity above the tropopause, decreasing with altitude, changes to an easterly direction, and usually does not exceed 10-15 m/sec at these altitudes. Consequently, in the stratosphere the strength of the horizontal and vertical air circulation increases with altitude in winter, and decreases in summer. This comprises the main reason for the difference in the nature of processes occurring during winter and summer in the stratosphere, as well as the absence of intense transformations of the temperature and pressure fields, which are similar to those occurring in winter, at high latitudes during the summer.

When the deep, powerful atmospheric winds (frequently series of them) are localized in a definite region, significant changes in temperature and wind occur at this point at the higher level. The atmospheric winds, which reach levels of 20 km and more as they develop, remain strong and influence the layers lying above, since the general direction of the horizontal temperature gradient between the mean and high latitudes corresponds to an intensification of the circulation. The temperature field changes most vigorously in the intensifying, stratospheric frontal zones (Ref. 17). /32

When the temperature decreases in the cyclone system and increases in the anticyclones under different stages of development, its advective and adiabatic changes caused by vertical motion play a corresponding role (Ref. 18).

Advection plays the main role in the diurnal changes of the temperature field in a system of baric formations in the troposphere, although adiabatic changes also have a significant effect on reconstructing the thermobaric field. In the lower stratosphere, particularly in the clearly-expressed baroclinic zones, significant temperature changes occur due to the vertical motion of the air. These temperature changes usually exceed the advective changes (Ref. 13-15). This is primarily due to the fact that its horizontal gradients, as well as vertical gradients, are small in the lower stratosphere.

Troughs and ridges usually correspond to cyclones and anticyclones in the stratosphere. They are usually attenuated above the tropopause in the majority of cases, since the horizontal temperature gradient in the middle and upper troposphere is directed from a high-pressure region to a low-pressure region, in accordance with the conditions under which regions of high and low pressure are formed. According to data for January, 1960, the temperature difference between ridges and troughs on an isobaric surface of 500 mb is primarily 10-12° at the high latitudes, and 8-10° at the mean latitudes (see the table). In the upper troposphere the direction of the temperature gradient is reversed, which is caused by the higher position of the tropopause in anticyclones and ridges and by its low position in cyclones and troughs. During the stage of greatest development, as well as during the stage in which they are filled up and destroyed, the difference in the height of the tropopause between them is 2-3 km for the most part.

TEMPERATURE DIFFERENCE IN RIDGES AND TROUGHS IN
DIFFERENT ISOBARIC AREAS IN THE TROPOSPHERE AND
STRATOSPHERE OF THE NORTHERN HEMISPHERE

Latitude °N	Isobaric Areas						
	500	300	200	100	50	30	10
Winter							
70	13	3	— 8	—1	—0	+1	—
60	11	4	—10	—1	—1	+1	—
50	9	4	—10	—3	—2	—2	1
40	8	3	— 8	—3	—2	—3	—
Summer							
70	5	4	— 6	—1	—1	—1	0
60	6	4	—10	—3	—1	—1	0
50	5	4	— 9	—3	—1	—1	0
40	2	0	— 2	—3	—1	0	0

Thus, somewhat below the tropopause the temperature is balanced between the high- and the low-pressure regions. Above the balancing level, the air temperature in the system of high cyclones and troughs is much

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higher than above anticyclones and ridges. This situation remains above the tropopause – in the lower stratosphere, where the temperature difference between them at one and the same latitudes in a 200 mb area is -8, -10° on the average during winter, and in individual cases reaches -15, -18°. In a 100 mb area, this situation is usually changed, and the magnitude of the difference decreases to -1, -3°. Just as in the areas (50, 30 mb) lying above, the sign of this difference changes during winter in the troughs and /33 ridges as a function of the nature of the processes.

In summer (July, 1950), the temperature differences differed from the winter differences in terms of absolute values. They were most frequently 6-8° in 500 mb areas at high and mean latitudes. In the lower stratosphere (200 mb), just as in winter, the signs were negative (-6, -10°). At higher points, in 100 and 50 mb areas, the temperature differences were primarily negative and small in terms of magnitude (-1, -3°). They were small in 30 and 10 mb areas. It can be stated that in a 50 mb area the air temperature is balanced in the ridges and troughs. The gradual attenuation of the meridional circulation, and the change to zonal circulation, during summer in the stratosphere is determined by the presence of a thermo-polar anticyclone and by the nature of the temperature distribution in the system of high ridges and troughs. Therefore, above 20-25 km the isohypses follow the latitudinal circle and are not formed similarly to the winter temperature anomalies.

However, during winter when the air circulation is close to zonal circulation, the center of the polar cold cyclone in the troposphere throughout the entire hemisphere expands into the region along the pole, not only into the upper troposphere but also into the stratosphere. When there is meridional circulation, which exists frequently and intensely during winter in the Northern Hemisphere, the center of the high polar cyclone is shifted for the most part from the polar region to different sides of the horizon. Interesting results (Ref. 19) have been derived from a study of the position of the center of the polar cyclone in different regions of the Northern Hemisphere in the cold half-years of 1958-1962 at the 23-24 km level.

It was found that the center of the polar cyclone over a period of 637 days was located in the region of the North Pole (85-90° N) for a total of 116 days, which amounts to only 18%. At the same time above northern Asia, including the underlying seas, this amounted to 31% of the days, and in northern Europe – 13% of the days. During the remaining period, its center shifted toward Greenland (9%) and Canada (5% of the days). It should be pointed out that for 24% of the days the polar cyclone had two centers. One of these centers was located over northern Asia; the other was located over Canada. A bifurcation thus occurred in the troposphere. Thus, the center of the polar cyclone in the cold half of the year was most frequently located not in the polar region, but was shifted toward Eurasia – i.e., it was not circumpolar as it is usually called.

The frequent shift of the polar cyclone center in the stratosphere toward northern Asia is usually accompanied by an anomalous temperature rise in the Pacific Ocean region of the Arctic. Apparently, these

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phenomena are closely related. They result from the development of macroprocesses in the hemisphere, and they must be studied simultaneously.

In order to determine the conditions under which the processes developing in the troposphere have a significant influence on the temperature field and the circulation in the stratosphere, we can examine the features of the cyclones reaching the lower stratosphere.

The recurrence of intensely-developing tropospheric cyclones is not in accordance with their recurrence in the lower stratosphere. At high altitudes, cyclones are usually discovered above the northern regions of the hemisphere, most frequently above the continents and rarely above the oceans. The lack of agreement between their recurrence on the earth and in the mean troposphere (on a AT-500 map) was discovered previously (Ref. 20, 21). It is natural to assume that the deeper the cylone extends, the more likely it is to be detected in the upper troposphere and the lower stratosphere. For purposes of verification, maps showing the recurrence of cyclones over 12 winter months of 1958-1962 were constructed, based on the methodology usually employed for this purpose - they were recorded on maps divided into quadratures which are equal in area, for the following areas: earth, AT-500, AT-100, and AT-10 based on maps of the Central Institute of Forecasting and the Bulletin of Berlin University (Ref. 22).

Cyclones have been recorded on the earth's surface having a depth /34 of 980 mb; at AT-500 - 512 decameters; at AT-100 - 1536 decameters; and at AT-10 - all cyclones including individual disturbances arising and disappearing in 1-2 days. Even for deep cyclones having a pressure of 980 mb at the center, the relationship between their recurrence on the earth and at high altitudes is complex. Actually, they are most frequently observed on the earth over the northern regions of the Atlantic and the Pacific Ocean (from 40 to 50 per quadrature). It is characteristic that there is one center of greatest recurrence over the Atlantic, and there are two over the Pacific, while both are located in the latitudinal zone of 50-70°N. In the 500 mb area, the greatest recurrence of cyclones, with a value of $H \leqslant 512$ decameters at the center, occurs in northern Canada, the Taimair Peninsula, and the Far East. This correction introduces a temperature field into the troposphere. But, nevertheless, in the mean troposphere the recurrence of deep cyclones over the oceans is still large.

As is known, the field of absolute geopotential at altitudes is de- /35 termined by the relationship $H_p = H_{1000} + H^p_{1000}$. Out of the two terms in the right part of this equation, the second term usually plays the larger role at altitudes - i.e., the temperature of the air layer lying below. The role of temperature constantly increases with altitude, which follows from the map of cyclone recurrence in areas of 100 and 10 mb (Ref. 19). Thus, in a 100 mb area the recurrence of closed cyclone formations considerably increases over the northern regions of the continents, and sharply decreases over the northern regions of the oceans.

As a rule, in a 10 mb area cyclones are concentrated to the north
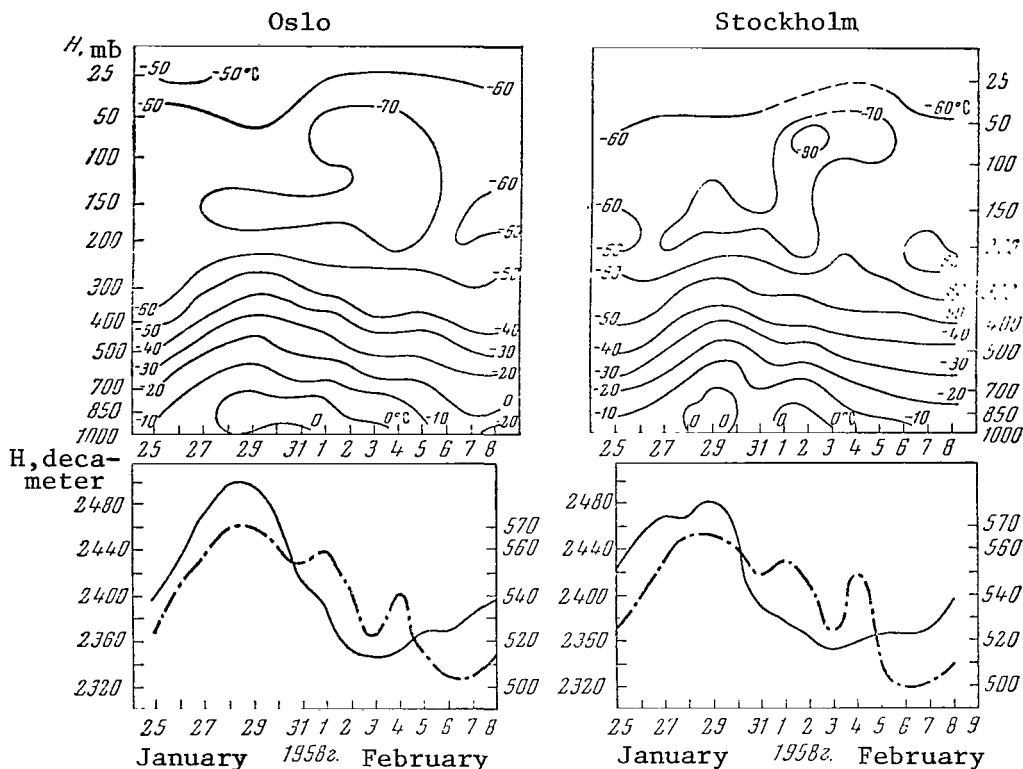
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Figure 1

Air Temperature Change in the 25-1000 mb Layer (Above) and
Change in Absolute Geopotential In 500 and 25 mb Areas (Below)
From January 25 to February 8, 1958 Over Oslo and Stockholm

Dotted Line - 500 mb; Solid Line - 25 mb

of the 50° latitude, with greatest recurrence in northern Greenland and
Eurasia. Attention should be called to the fact that in a 100 mb area
cyclones having a depth of 1536 decameters were not observed over a
period of four years during the winter months in western North America
and Alaska, while in a 10 mb area they were completely absent in a large
portion of the eastern Arctic. Although the role of temperature in forming
the absolute geopotential field in the stratosphere is great, nevertheless
the factor H_{p0} frequently introduces significant changes into the struc-
ture of the isohypses and circulation, not only in the lower stratosphere
but also in the mean stratosphere.

In order to demonstrate the influence of these factors on the change
in the geopotential field (H) and circulation in the stratosphere, we shall
present several graphs showing the changes in H in different areas in
different regions of the Northern Hemisphere during one and the same periods
of time. The curves in Figure 1 show significant, but uniform changes in
H in the troposphere (500 mb) and the stratosphere (25 mb) from January 25
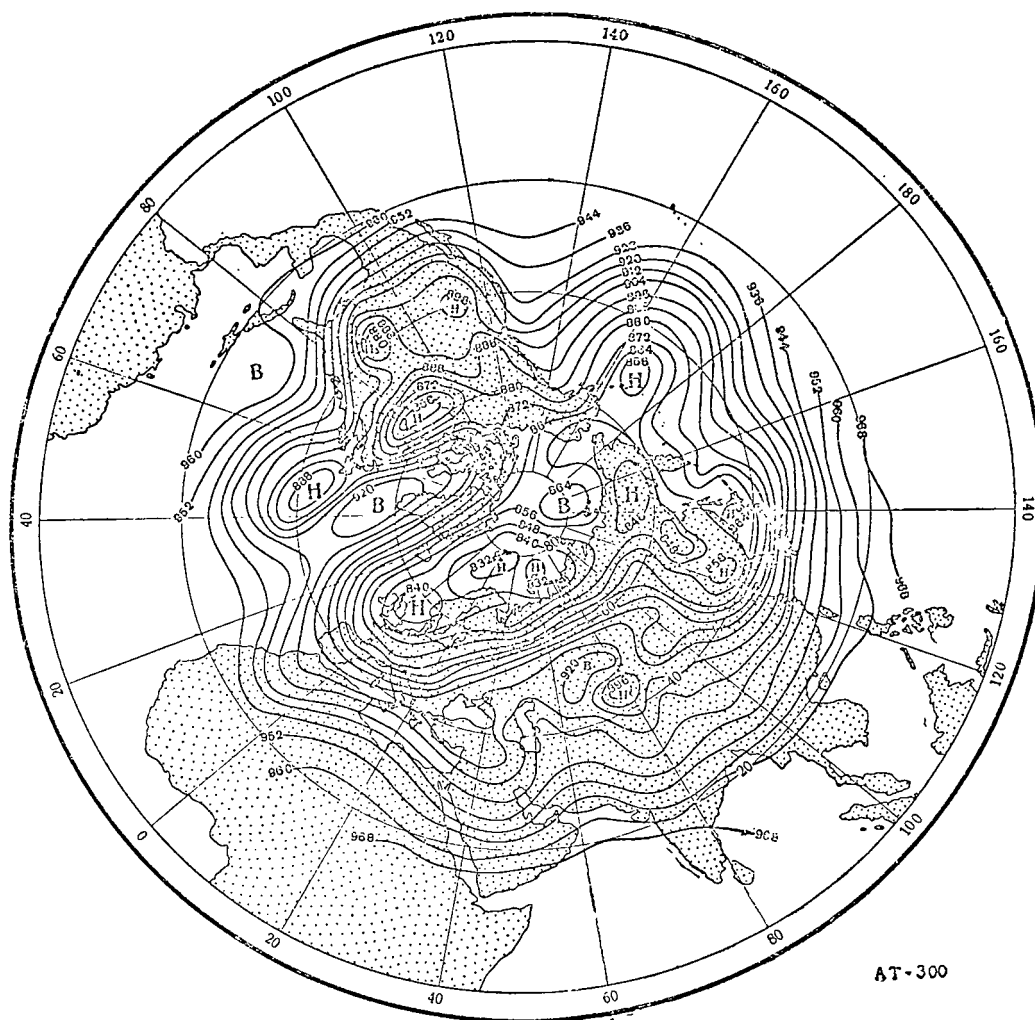to February 8, 1958, over Oslo and Stockholm. As can be seen, the increase

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Figure 2a

AT-300 Map for January 22, 1958

at the beginning and the decrease during the following days in the geo-
potential by 50-60 decimeters at 500 mb, and 100-150 decameters at   /36
25 mb, is accompanied by a small temperature drop in the troposphere
and a slight temperature increase in the stratosphere. Small distur-
bances, which are reflected in the 500 mb area, very frequently have
no influence on the H = 25 mb field.

The reason for the uniform changes in H in the troposphere and
the stratosphere during the last decade of January, 1958, can be found
in the anticyclone genesis over middle and northern Europe. From January
22 to January 28, H increased by 100-120 decameters in the stratosphere
(25 mb) over middle Europe. Out of these numbers, about 60 decameters
belong to the troposphere, and only 50 decameters to a temperature in-
crease in the stratosphere. As the anticyclone intensifies on the earth's
surface and throughout the entire troposphere, the geopotential increases
at the higher levels above all of Europe. In accordance with the cyclone
pattern in the Atlantic, a zone is created over the northern half of
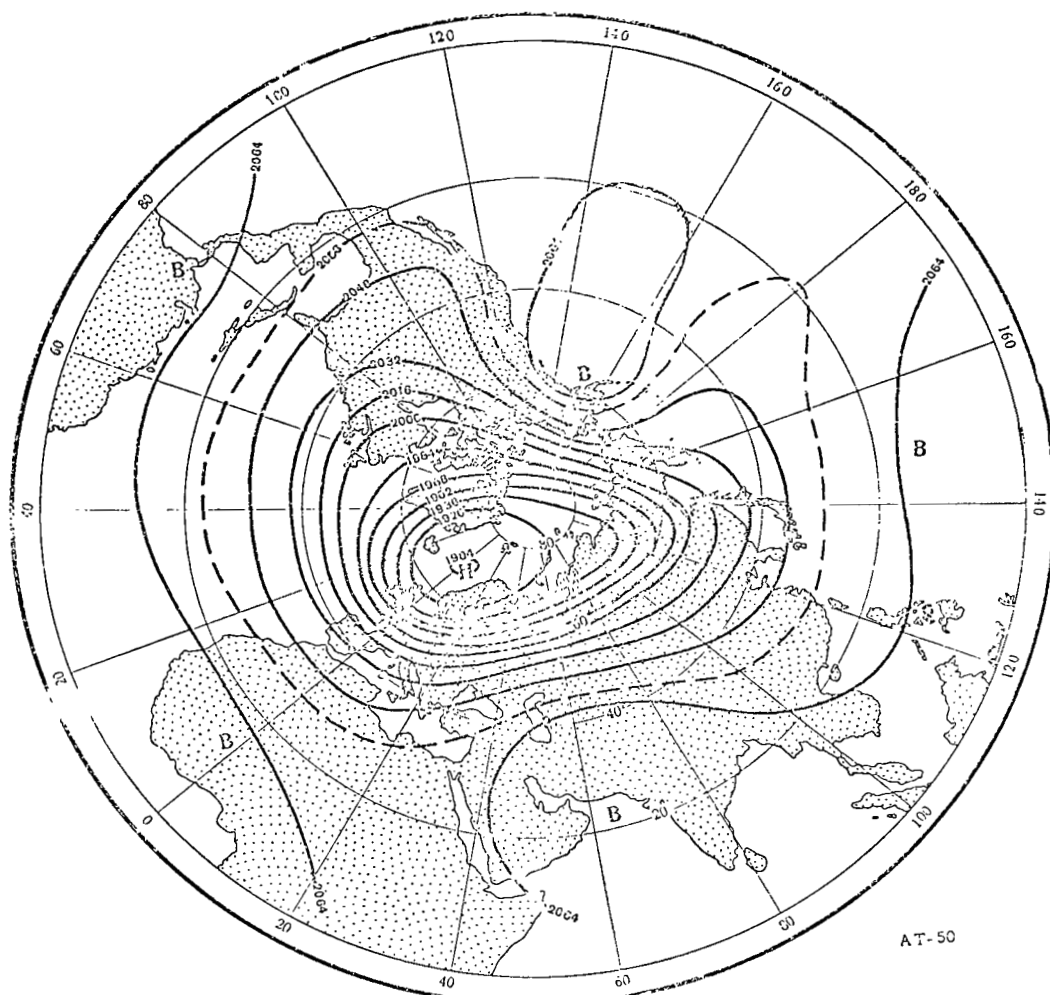
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Figure 2b

AT-50 Map for January 22, 1958

Europe in which the currents converge with large wind velocities and
temperature contrast. Descending air movements and a certain increase
in air temperature are observed in this zone.

Changes in the geopotential field in the troposphere and strato-   /37
sphere during this period are represented in the AT-300, AT-50 and AT-10
maps for January 22, 25, and 27 (see Figures 2, 3 and 4). Judging by
the AT-300 map (Figure 2a), on January 22 there was a trough over
western Europe which, as a result of the incipient anticyclogenesis
process, was gradually filled up (Figure 3a). On January 27 the area
was conceded to an anticyclone, which was clearly expressed not only in
the upper troposphere but also in the mean stratosphere (Figure 4a). By
this time, the pressure in the center of the anticyclone close to the
earth reached 1045 mb.

At the same time, in northern Canada the temperature decreased with
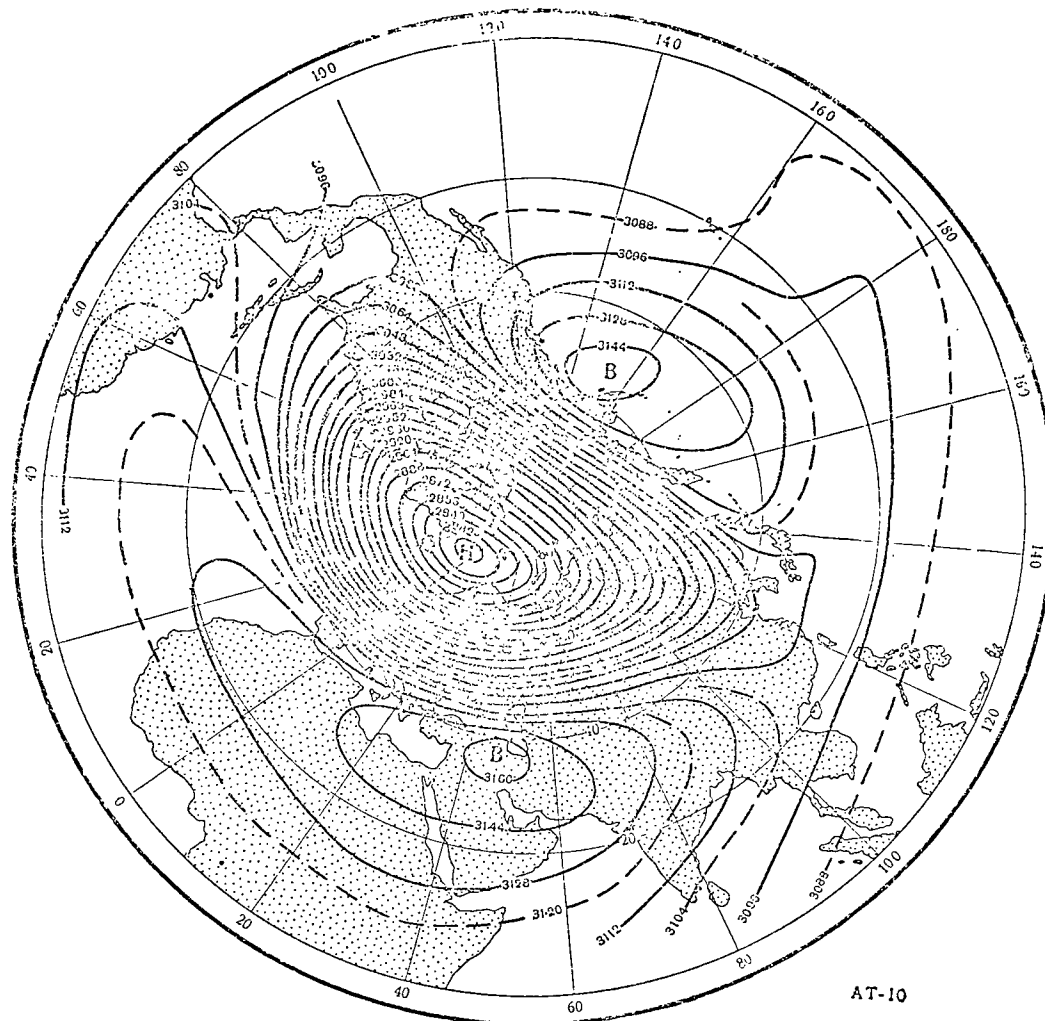an increase in the cyclone pattern in the troposphere, while in the

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Figure 2c

AT-10 Map for January 22, 1958

stratosphere, on the other hand, it increased. As can be seen from Figure
5, the pattern of the geopotential curves for H-500 and H-25 is just the
reverse of the current in Figure 1. In Eureka and Alert, when there was
a small temperature increase in the troposphere between January 21 and
January 24, the magnitude of H increased somewhat in both areas. After
January 24-26, the temperature dropped almost continuously due to the
development of cyclones in the troposphere, while in the stratosphere it
increased. As a result, from January 24 to February 1, there was an
increase in H in the stratosphere, while it decreased in the troposphere. /38

Graphs compiled for the region of southern Greenland, northeast
Asia, the Baykal region, northern Scandinavia, etc. have not been pre-
sented here, since in many ways they are similar to the graphs shown in
Figures 1 and 5. Some of the graphs were constructed for the periods of
January 4-18 and January 18-31, 1960, in different regions of the Northern
Hemisphere. All of these periods are characterized by the bifurcation of
a stratospheric polar cyclone. We shall examine one of the cases in which
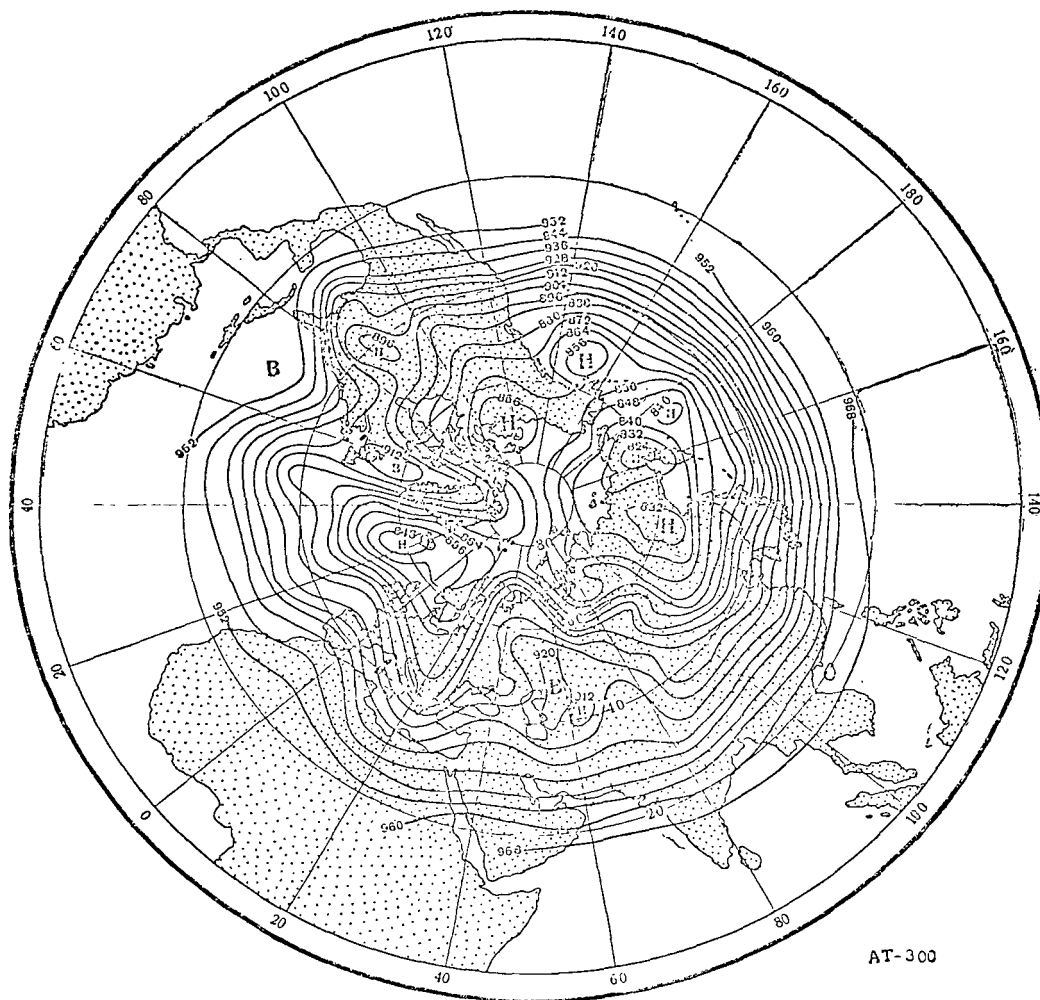
10

Figure 3a

At-300 Map for January 25, 1958

two cyclones merged in the stratosphere during the period from January
18-31, 1960, which was accompanied by a significant decrease in H in
the troposphere and stratosphere over North America.

Figure 6 presents curves for the change in the absolute geopoten-
tial and temperature of the main isobaric areas over northern Canada at
the points a and b. At point a, H decreased at all altitudes between
January 18-25, and then it increased a compartively small amount. At
point b, which is located somewhat to the northeast, H decreased almost
continuously from January 18 up to January 28-29. The high-pressure
region, which was formed before January 18 over western Canada and Alaska,
began to be disturbed, and by the end of the month an extensive cyclone
had arisen over the Arctic and the adjacent regions (Figure 7).

Data on the temperature change in the troposphere and stratosphere
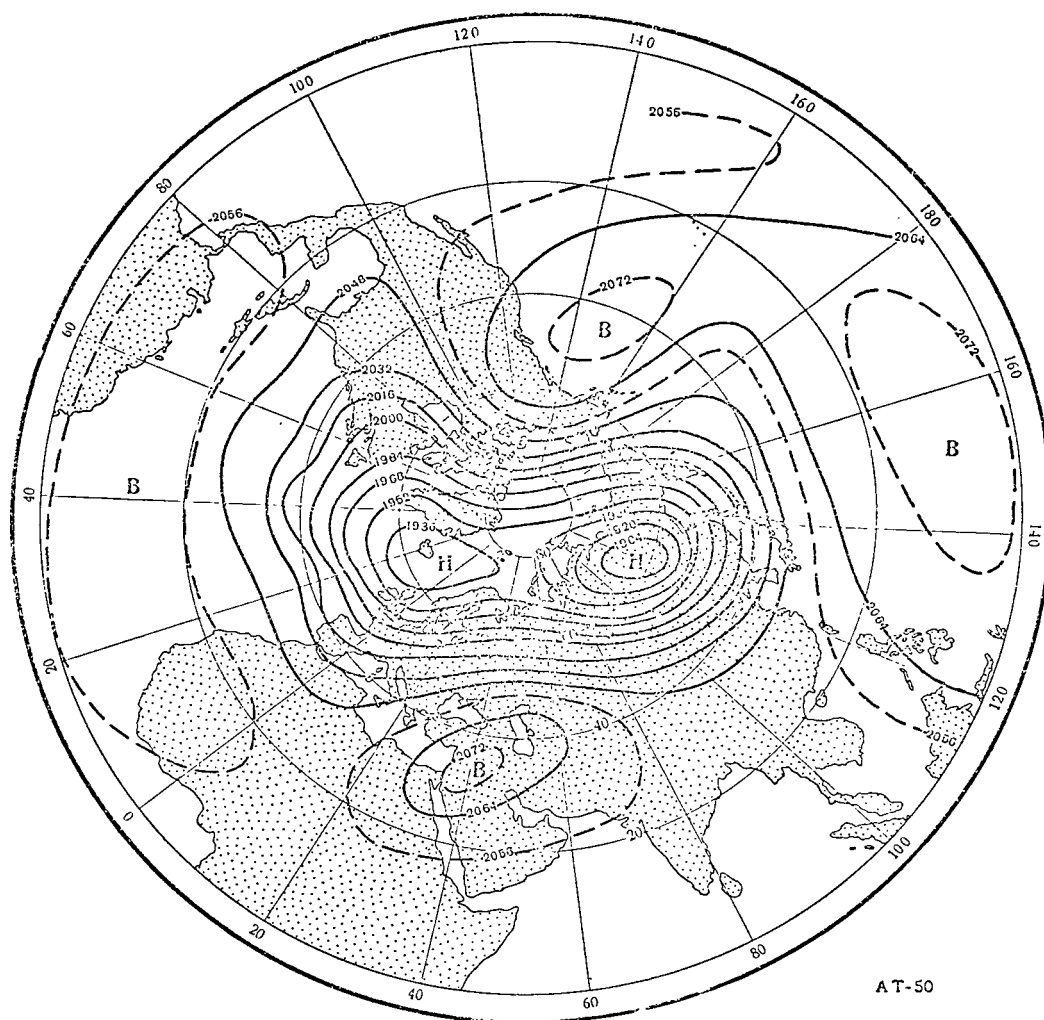during this period (Figure 6) showed that there were no significant

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Figure 3b

AT-50 Map for January 25, 1958

temperature changes in either sphere (see dashed curves). At the same time, the magnitude of H considerably decreased in all areas. In particular, the magnitude of H decreased by more than 100 decameters over northwestern Canada in the 30 mb area, and it decreased by 60 decameters - in the 300 and 500 mb areas.

This example of a reconstruction of the pressure field and atmospheric circulation at altitudes up to 30 km, and apparently even higher, also demonstrates the fact that this reconstruction is caused by the development of tropospheric cyclones over northern Canada and in the polar region. A cyclonic vortex arises in the stratosphere, due to the development of cyclones and to the decrease in temperature and H in the troposphere. Small changes in the temperature field in the stratosphere can be explained by the absence of strong meridional transformations of the thermobaric field in the troposphere. On the other hand, during the /40 last decades of January the meridional circulation, which had been strong
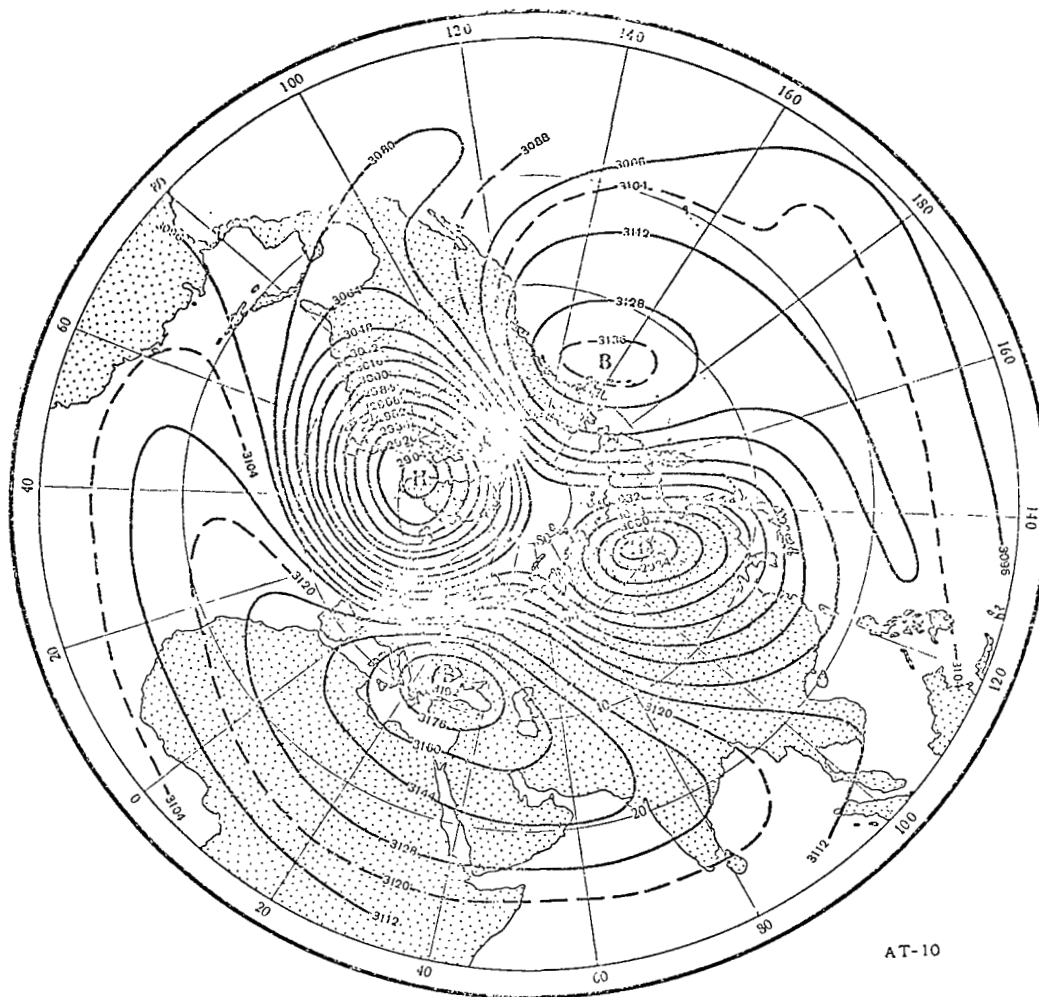
12

Figure 3c
AT-10 Map for January 25, 1958

up to this time, gradually diminished over the entire hemisphere.

All of these data confirm the fact that a change in H at altitudes including the stratosphere depends not only on the temperature change in the different layers, but also on the vortex activity.

The results derived from the study enable one to formulate certain assumptions regarding the nature of the diverse and complex combination of changes in pressure near the earth, temperature, and absolute geopotential in the troposphere and the stratosphere. An assumption may also be formulated regarding the role of cyclone activity in the processes by which the thermobaric field is transformed in the stratosphere.

It was already indicated above that anomalous temperature rises in the Arctic are caused by the strong development of cyclones and anticyclones, accompanied by intense meridional circulation. Some of the
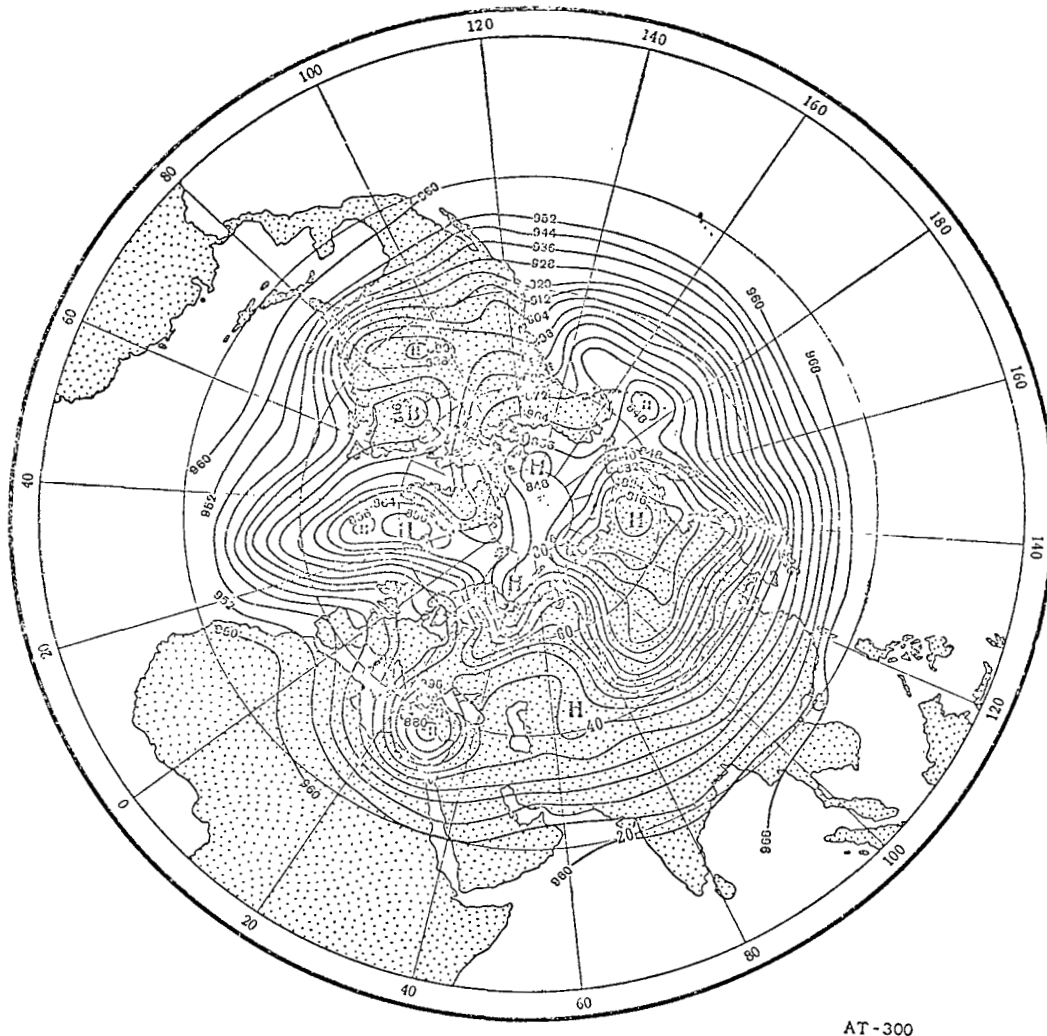
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Figure 4a

AT-300 Map for January 27, 1958

studies have analyzed the thermobaric field and have clarified the decisive factors influencing the temperature field change in the stratosphere. Geostrophic advection and adiabatic temperature changes represent such factors (Ref. 12-15).   Calculations of advective temperature changes, em- /41 ploying a graphic or analytical method by means of computers, have shown that they correctly characterize in general the advection which is actually observed. Several methods have been employed (Ref. 23) to calculate the velocity of vertical air motion (W), in order to compute the adiabatic temperature changes.

In recent years attempts have been made to calculate W, in order to determine the temperature change in the stratosphere. Adiabatic computational methods are usually employed for this purpose. A method based on the difference in the local and advective temperature changes was employed
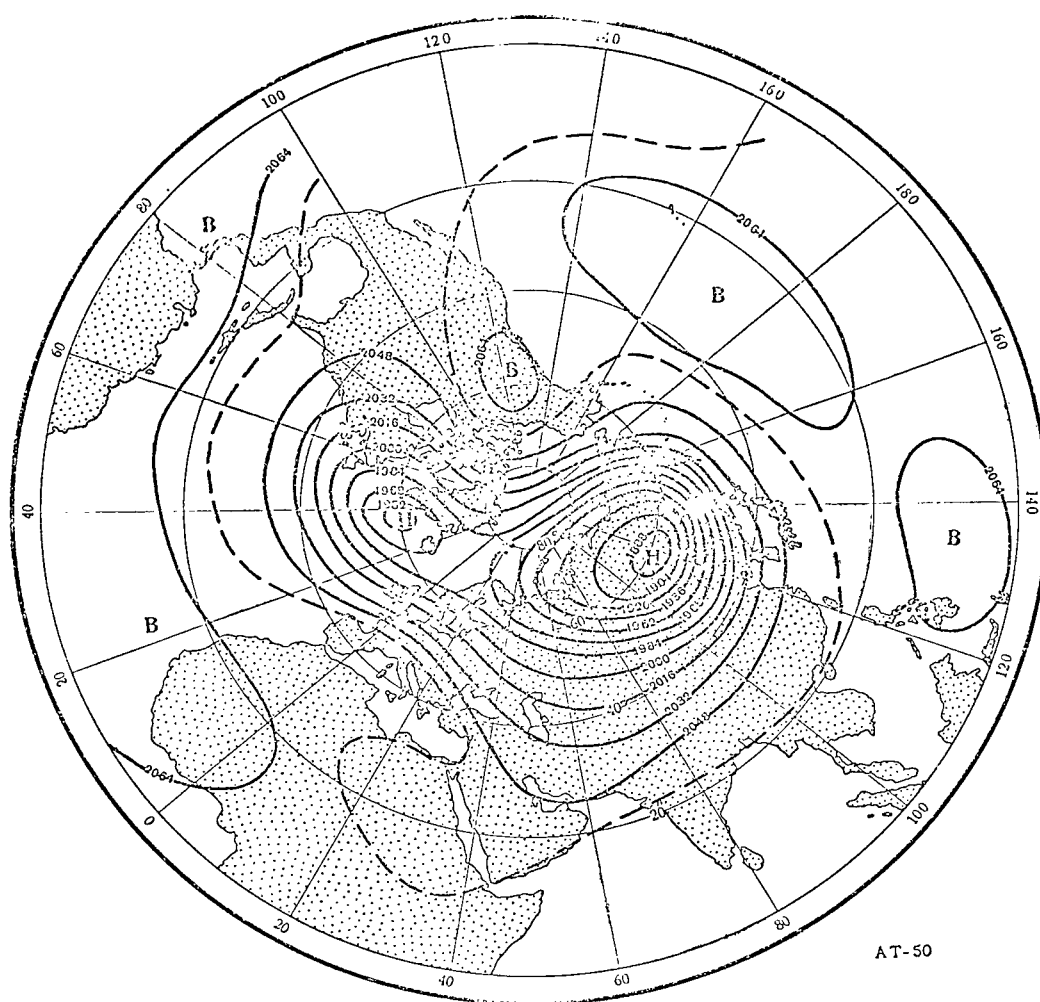
14

Figure 4b
AT-50 Map for January 27, 1958

by the authors to determine W in studies carried out in 1959-1962.

Control calculations of non-advective temperature changes, performed for several cases by two methods, for the lower half of the troposphere have shown that they reflect almost the identical sign and magnitude of vertical air motions. Verification was thus made on the basis of data regarding the occurrence or absence of precipitation. This provided a basis for assuming that non-advective temperature changes in the stratosphere can be determined in the first approximation, just as in (Ref. 23), by the difference in its actual and advective changes.   /42

W can be calculated more accurately in the stratosphere by the adiabatic method than it can be in the stratosphere.* This is due to

* Translator's Note: This is an obvious typographical error in the
                      original text.

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Figure 4c

AT-10 Map for January 27, 1958

the nature of the temperature changes in the stratosphere during short
periods of time. They extend for a longer period of time than in the
troposphere. Diurnal temperature changes in the stratosphere due to
radiant heat exchange are small (Ref. 24, 25). In addition, the verti-
cal temperature gradient in the stratosphere is smaller, and the scale
of the thermobaric field is greater. The effect of latent heat on the
temperature field change can be completely excluded above the tropopause.

    R. A. Kreyg and M. A. Letif (Ref. 26), who calculated W on the
basis of the adiabatic form with the aid of computers, found that the
magnitude of W is approximately the same as in the troposphere. Thus,
on the 100 mb level W was about 4 cm/sec; on the 50 mb level - 6 cm/sec;
and on the 25 mb level - 8 cm/sec.

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In the majority of cases, the descending motion occurred in the high troughs, and the ascending motion - in the high ridges. Local $/43$ temperature changes were usually confined to 2-4° since their advective changes were compensated for by adiabatic temperature changes in the majority of cases. Just as in the troposphere, in the rear portion of a high trough, strong cold advection is attenuated by the descending movements of air, and in the rear portion of a ridge, on the other hand, heat advection is attenuated by ascending motion. The signs of these changes coincide, and the temperature field and circulation are recon- structed only under definite conditions.

The fact that during winter the magnitude of W increases somewhat with altitude in the stratosphere is apparently connected with the general intensification of the wind, due to an increase in the horizontal temperature gradient with altitude. Temperature advection also takes place more strongly in the 10 mb areas, than it does in the lower level of the stratosphere. At the same time, the vertical temperature gradient usually approximates 0° up to an altitude of 10 mb.

The works (Ref. 13 and 14) present the results derived from calcu- lating temperature changes in the stratosphere of the Arctic and the moderate latitudes for several cases of anomalous winter temperature rises in 1957-1959. They also showed that advection and adiabatic $/44$ processes play a significant role in the air temperature change in the lower stratosphere.

The role of temperature change is undoubtedly large in the recon- struction of the geopotential field and air currents in the stratosphere. At the same time, tropospheric processes are usually decisive in these changes, because transformations of the meteorological fields in the stratosphere follow their transformations in the troposphere. However, as we have seen above, fluctuations in the pressure near the earth (H-1000) and the temperature in the troposphere have a significant effect on these processes. This is due to the fact that cyclones and anticyclones, when they are strongly developed, have a direct influence on the structural change in the geopotential field and the air currents in the stratosphere.

The temperature field in the troposphere, which is formed as a result of heat exchange with the underlying area and of atmospheric dynamics, greatly influences the formation of the absolute geopotential field in the stratosphere. In actuality, deep tropospheric cyclones frequently attain great altitudes. In a like manner, it appears that they must be frequently observed during winter in the mean stratosphere. Under the conditions of radiant heat exchange in the stratosphere, the cold region must be defined by the Arctic region on the average, more or less strictly along the latitudes. However, it can be seen from maps showing the recurrence of deep cyclones in different areas that in some regions they attain high altitudes compara- tively frequently, while in other regions - they are rarely detected
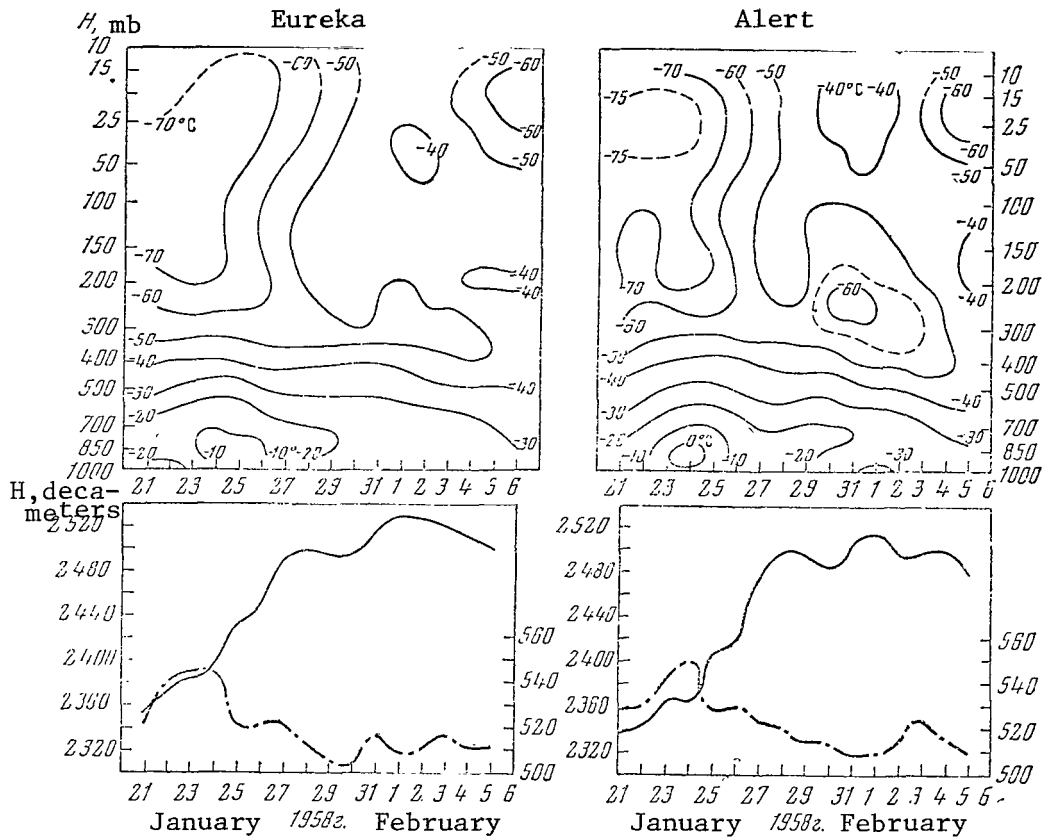
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Figure 5

Air Temperature Change in the 10-1000 mb Layer and Change
in Absolute Geopotential in 500 and 25 mb Areas From
January 25 to February 9, 1958, Over Northern Canada
(Eureka and Alert)

Dotted Line - 500 mb; Solid Line - 25 mb

even in the 100 mb area. In particular, in the northern Pacific   /45
Ocean, south of Alaska, where there is frequent recurrence of deep
cyclones in the troposphere, they are detected rarely in the 100 mb
area. The same is true for the moderate zone of the hemisphere.

Consequently, the extension of the cyclonic form of circulation
up to the mean stratospheric layers depends on the temperature back-
ground at altitudes supporting or impeding the extension of the cy-
clonic vortex in the upward direction. It is apparent that deep troughs
or cyclones appear during winter in the upper troposphere, most fre-
quently above the coldest regions of the continents of Asia and North
America. The lowest values in their system are observed during the   /46
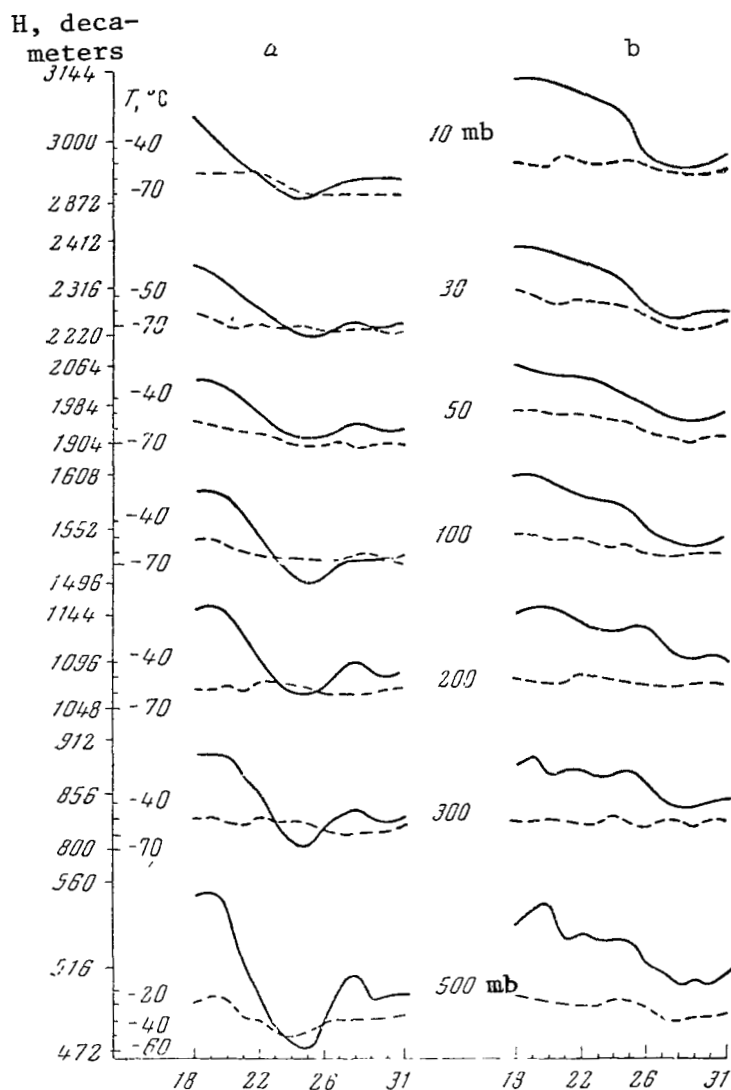
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Figure 6

Changes in the Magnitude of H (Solid Curve) and T° (Dashed Curve) in the Isobaric Areas from January 18 - 31, 1960 over Northern Canada at Points a and b.

a- $\varphi = 73°$ N, $\lambda = 80°$ W;   b- $\varphi = 70°$ N, $\lambda = 135°$ W.

period of maximum deepening and during the initial stage during which the cyclones are filled up in eastern and northeastern regions of the continents. This can be explained by the congruence between the small or negative values of H-1000 and the low values of OT^{300}_{1000} in the

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rear portion of the cyclones, particularly during the stage in which they are filled up. It is important that they are imposed on a low background of air temperature over the cold continents.

During 24% of the days, a polar stratospheric cyclone has two centers. Its bifurcation is caused by the development of deep cyclones in northern and eastern Asia and North America. The center of the polar stratospheric cyclone during 55% of the days is shifted toward Asia. This can apparently be explained by the fact that conditions are created for more significant radiation cooling of air over the extensive area of northern Asia during winter than over North America. This phenomenon is clearly expressed in the mean seasonal map of OT^{300}_{1000}, where the relative geopotential in the stratosphere is 12 - 17 decameters less, or 3 - 5° less, over the eastern portion of Asia than it is over the eastern portion of North America. Moreover, the cold and the low /47 geopotential value extend much further to the south than over America, which creates a strong meridian effect in eastern Asia.

Thus, radiation conditions in the troposphere contribute to a partial shift in the center of the stratospheric polar cyclone toward Asia, but they are most clearly apparent when deep cyclones are formed and develop in eastern Asia. In these cases, the rear, cold portion of the cyclone coincides with the low temperature background over the eastern portion of the continent. As a result, low geopotential values, which are formed in the mean and upper troposphere, affect the structure of the field for H in the lower stratosphere.

Analogous processes occur over North America, but on a much larger scale due to the comparatively small size of the continent. However, during the periods when deep cyclones develop in the eastern portion of the continent, low values of H are formed in the troposphere, as was the case in January, 1961. The center of the stratospheric polar /48 cyclone or trough is accordingly shifted toward North America. Independent cyclone centers are frequently formed in high isobaric areas (50, 30, 10 mb).

These processes are accompanied by significant meridional transformations of the thermal and baric fields both over eastern Asia, and over eastern North America. In contrast to North America and the Atlantic, there are not one, but two, regions in which deep cyclones arise and are developed under the physico-geographical conditions of eastern Asia and the Northern Pacific Ocean. The first of these regions is caused by large contrasts in the air temperature at the junction of the oceans and the continent (over the Japanese islands). The second region occurs in the zone of large temperature contrasts between the cold air in the region of Alaska and the warm air masses over the ocean.

With the development of a depression in eastern Asia, the high trough over the continent and the ridge over the ocean are constantly
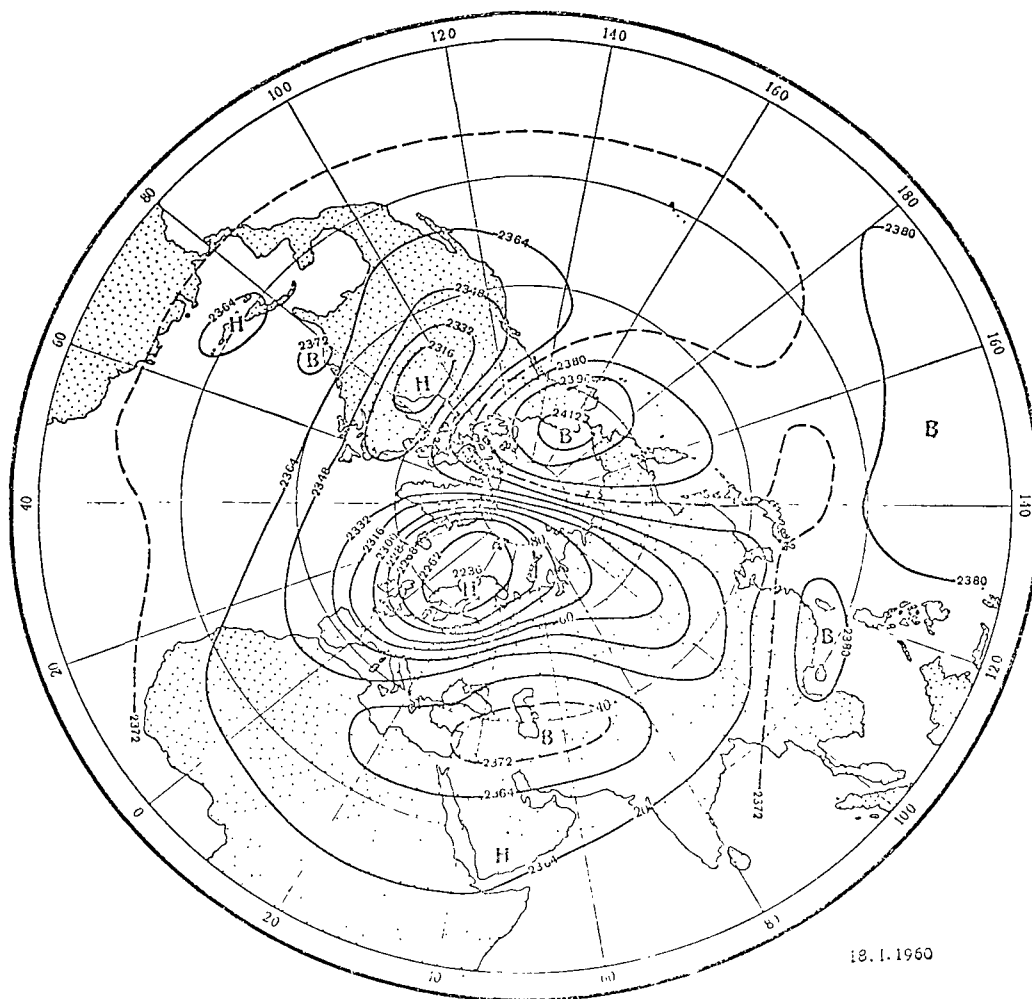
Figure 7a

AT-300 Map for January 18, 1960

deepened, and the meridional circulation is intensified. In the system
of deep cyclones which develops simultaneously in southern Alaska, there
is a general temperature increase above the tropopause (Ref. 14), which /49
assists in changing them into a high-depression trough in the lower
stratosphere (14-16 km) in eastern Asia. Under these conditions, the
advection of heat toward the Central Arctic and the convergence of air
currents are intensified, in the region of which an adiabatic temperature
increase occurs. During the duration of these processes, the region
of stratospheric heat is gradually shifted to the north, and there is
an anomalous temperature rise at the high latitudes, under the conditions
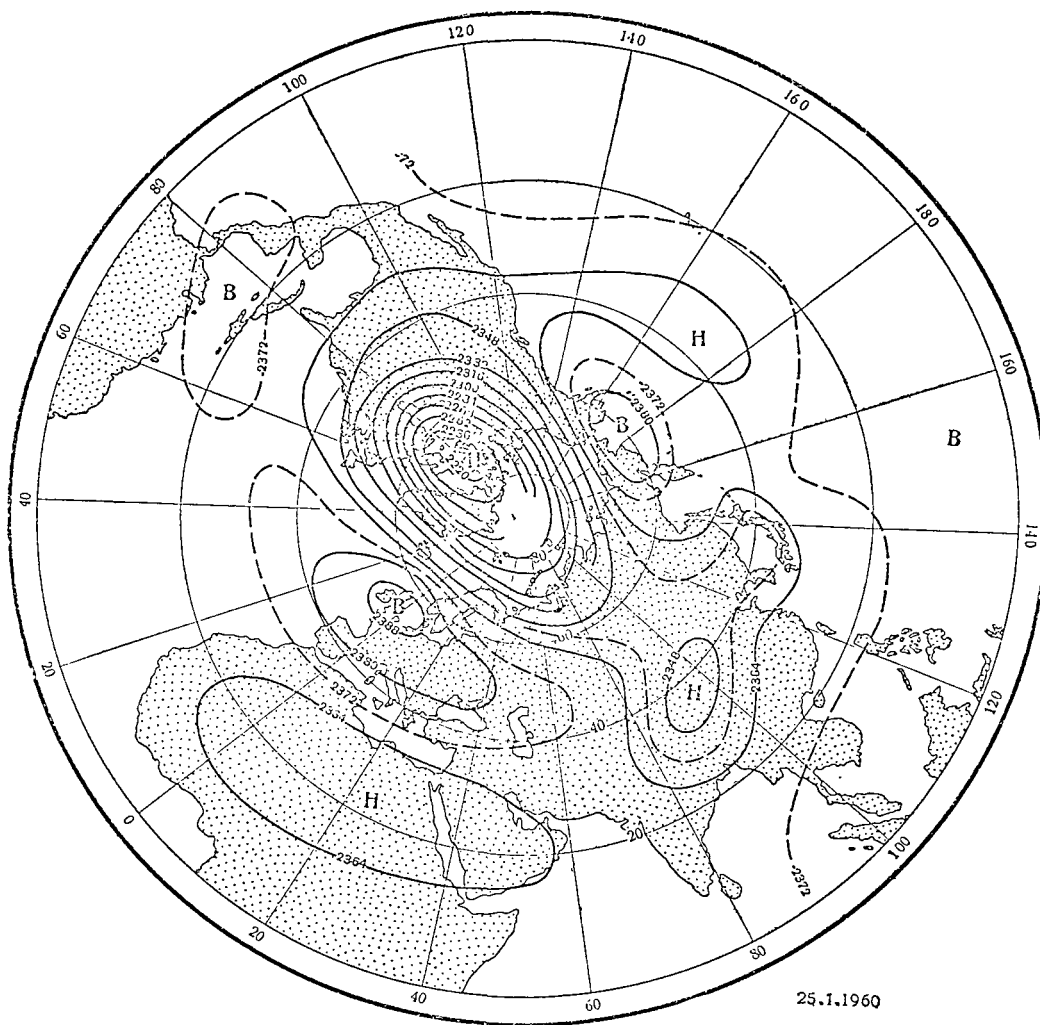of the polar night.

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Figure 7b

AT-300 Map for January 25, 1960

These processes are so frequent that they are shown on mean maps of
baric topography. For example, in spite of the fact that the recurrence
of deep cyclones is more frequent to the south of Alaska than it is in
eastern Asia, during the winter months the geopotential difference between
these regions is 45-50 decameters at 60° latitude in 100 mb areas - i.e.,
a high trough is more clearly defined over eastern Asia than over Alaska.

Although tropospheric processes play a significant role in the forma-
tion of temperature and circulation anomalies in the lower and mean
stratosphere, the influence of a high-temperature layer in the upper
stratosphere must not be overlooked. When there are meridional transfor-
mations of the field in activated baroclinic zones, the air drops down
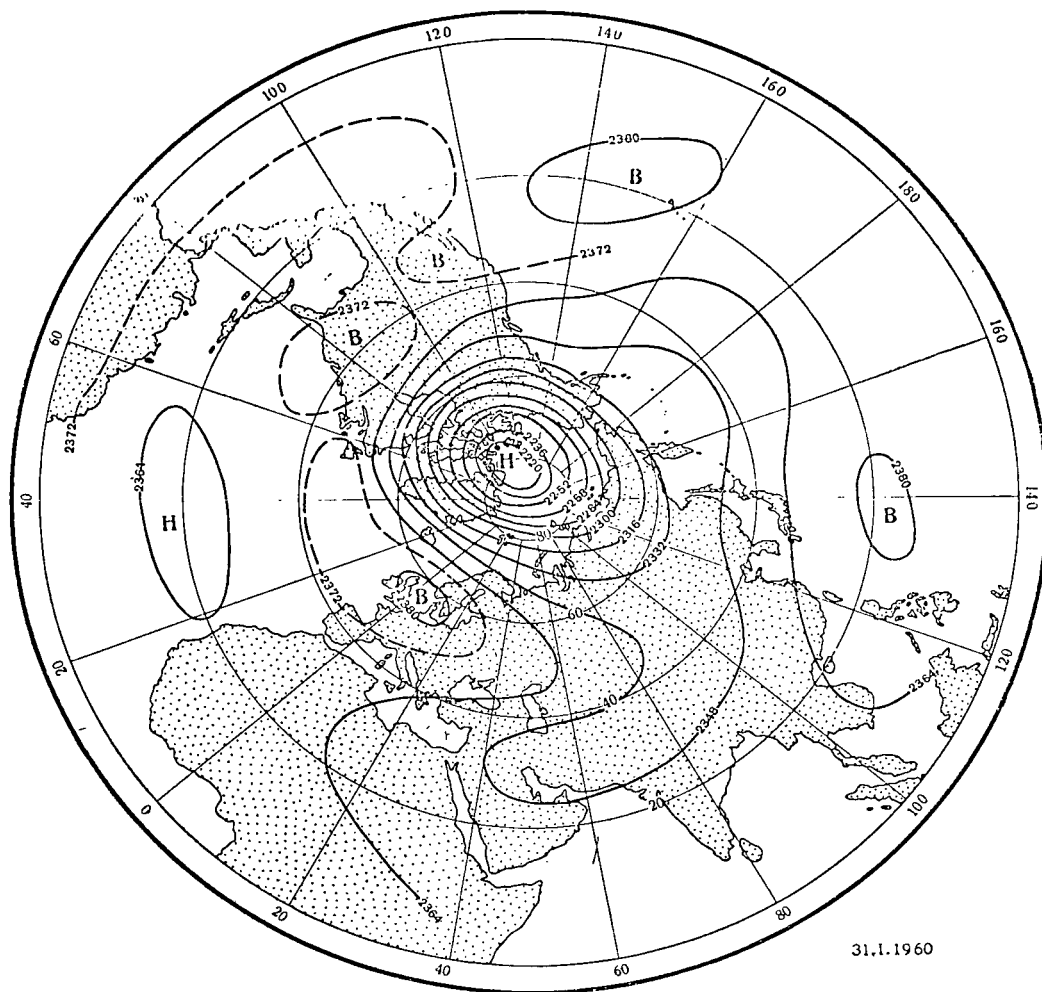
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31.1.1960

Figure 7c

AT-300 Maps for January 31, 1960

with high temperatures from altitudes of 40-50 km, even in the case of
small vertical velocities. Combined with the processes in the lower
stratosphere, an adiabatic temperature increase contributes to the inten-
sification of the meridional circulation in the upper stratosphere and,
apparently, in the lower portion of the mesosphere. When we speak of
the role played by vortex activity and meridional transformations of air
currents in the troposphere in changing the temperature and circulation
fields in the stratosphere, we have in mind not only the strength of vor-
texes and intralatitudinal air exchange in limited regions of the hemi-
sphere (Ref. 27), but also the scale and localization of this exchange.
This is due to the fact that even during winter the meridional circula-
tion is more intense in the moderate zone of the Southern Hemisphere

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than it is in the Northern Hemisphere.

When speaking of the large scale intralatitudinal exchange in the Northern Hemisphere (in comparison with the Southern Hemisphere), we mean the active air exchange between mean and high latitudes which takes place in a localized manner due to the effect of the underlying area under definite physical-geographical conditions. This is the case for the Northern Hemisphere, where the influence of the underlying area on the formation of a seasonal temperature field and air currents is not confined to the troposphere, but extends to the lower level of the stratosphere (Ref. 28). The modest scale of localized air exchange between mean and high latitudes in the Southern Hemisphere can be explained primarily by the uniformity of the underlying area at the mean and high latitudes, where there are no conditions for the localization of cyclonic activity or for the development of significant intralatitudinal air exchange in the troposphere and the stratosphere between the subtropics and the Central Antarctic in the same scale that this frequently occurs in the Northern Hemisphere (Ref. 29).

We would like to say a few more words about the effect of solar activity on atmospheric processes. There is no doubt that a change in solar activity is reflected in atmospheric processes and phenomena. During the last century, many studies have been devoted to establishing this relationship. Since solar energy primarily causes the occurrence and development of atmospheric circulation, it is necessary to know the mechanism by which it is converted into energy of motion in the atmosphere.

It is assumed that during the period of maximum solar activity the amount of ozone is greater above 35 km than it is during the period of minimum solar activity. It follows from this that the total atmospheric circulation is influenced by O_3 and depends on solar activity. The re- /50 lationship of temperature changes and atmospheric density with solar activity should also be discussed. When the solar activity and the intensity of the short-wave solar radiation diminish, there is a density increase, etc. in the upper atmosphere.

It can be assumed that the short-wave radiation and other forms of solar radiation, which have an influence on the upper atmospheric layers, cause certain anomalies. However, up to the present no tenable hypothesis has been advanced to clarify the nature of the relationship between high atmospheric layers, the mesosphere, and the lower spheres. The anomalous temperature rises in the stratosphere of the Arctic and the moderate zone, as well as the temperature drops at the mean latitudes, can be explained primarily by processes developing in the troposphere, especially due to the fact that laws of hydrodynamics apply in both spheres.

It is possible that there is no basis for denying the direct influence of solar activities on changes in the temperature field and circulation in the stratosphere. However, this role is apparently small. The lack of winter analogous temperature anomalies in the Central Arctic,

as well as the lack of significant anomalies during summer at the high latitudes of both hemispheres, also substantiates this conclusion.

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